Field Evaluation
Aeroqual AQY (v0.5)

South Coast AQMD

AQ-SPEC
Air Quality Sensor Performance Evaluation Center

Background

- From 12/22/2017 to 03/27/2018, three Aeroqual AQY (Version 0.5) multi-sensor units were deployed in Rubidoux and run side-by-side SCAQMD Federal Equivalent Method (FEM) and Federal Reference Method (FRM) instruments measuring the same pollutants

- Aeroqual AQY (*3 units tested*):
  - Sensors: Ozone – Gas Sensitive Semiconductor (GSS); NO_2 – Gas Sensitive Electrochemical (GSE) (non-FEM/non-FRM); $PM_{2.5}$ – Laser Particle Counter (LPC) (non-FEM), (model SDS011 by Nova Fitness)
  - Each unit measures: O_3 (ppb), NO_2 (ppb), $PM_{2.5}$ ($\mu g/m^3$), T (degrees C), RH (%)
  - Unit cost: ~$3,000 (includes 2-yr tech support + cloud data software license)
  - Time resolution: 1-min
  - Units IDs: AQY 130, AQY 131 (AQY 134), AQY 132 (On 2/15/2018, entire unit AQY 131 was replaced by unit AQY 134 due to faulty NO_2 sensor)

- SCAQMD Reference instruments:
  - O_3 instrument (FEM); cost: ~$7,000
    - Time resolution; 1-min
  - NO_X instrument (FRM); cost: ~$11,000
    - Time resolution: 1-min
  - GRIMM (FEM $PM_{2.5}$); cost: $25,000 and up
    - Time resolution: 1-min
  - MetOne BAM (FEM $PM_{2.5}$); cost: ~$20,000
    - Time resolution: 1-hr
 - Met station (T, RH, P, WS, WD); cost: ~$5,000
    - Time resolution: 1-min

Ozone (O_3) in AQY

Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for ozone in the four AQYs was high (i.e., 92% for AQY 130; 76% for AQY 131; 97% for AQY 132 and 100% for AQY 134).
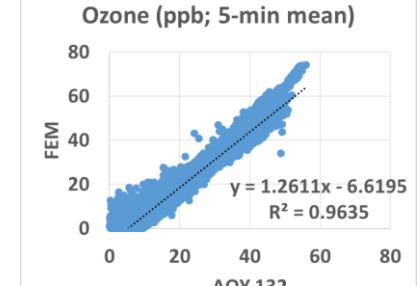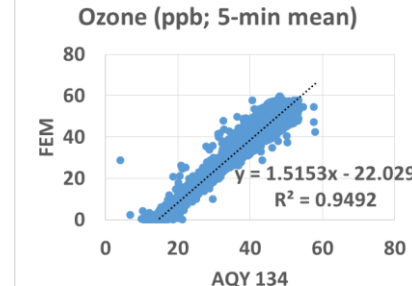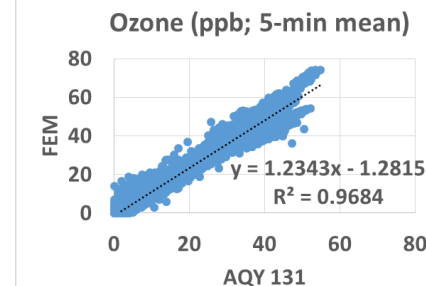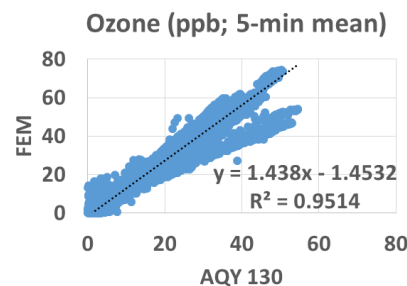
Aeroqual AQY; Intra-model variability

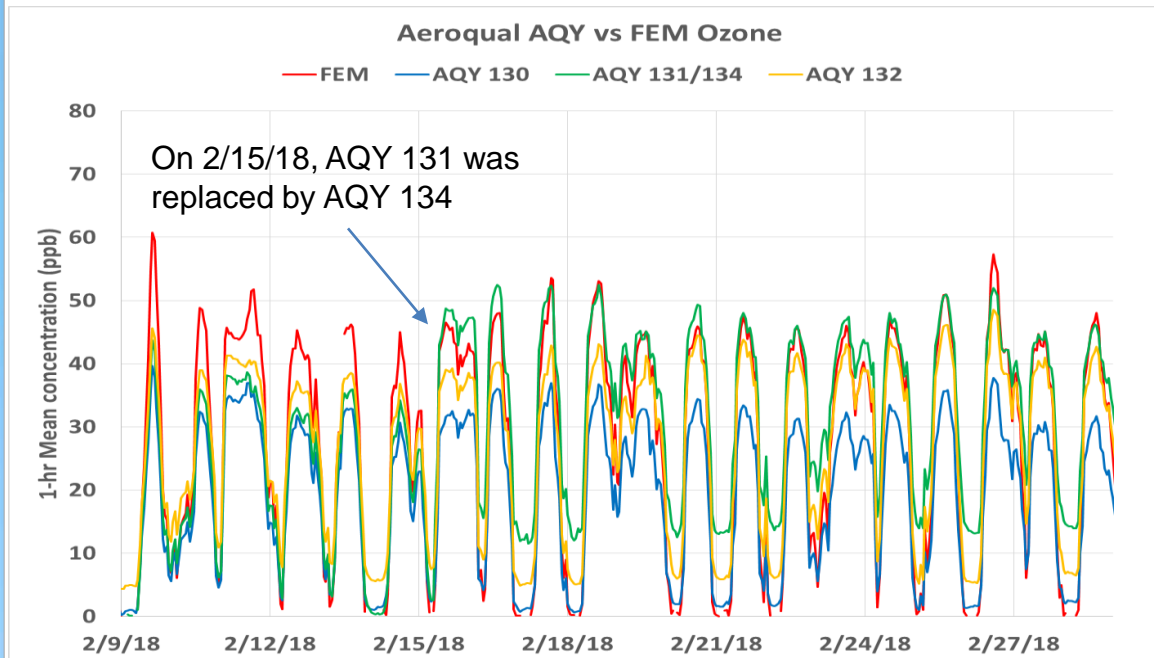- Low measurement variability was observed between the two AQY units (130, 132) for ozone during the entire deployment period.
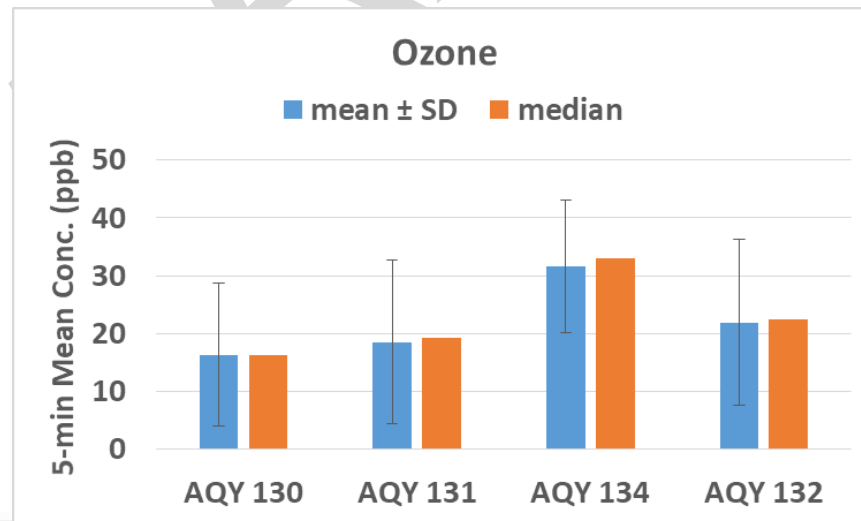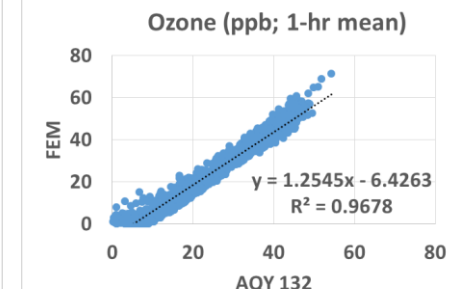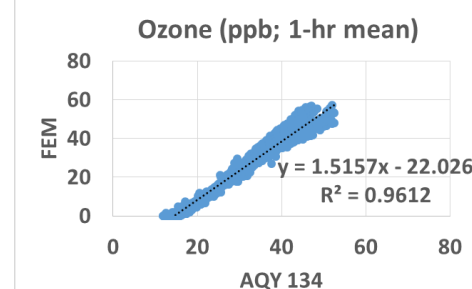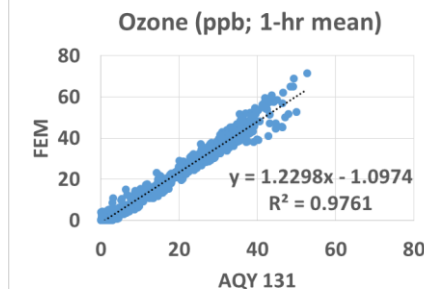
Aeroqual AQY vs FEM (Ozone; 5-min mean)
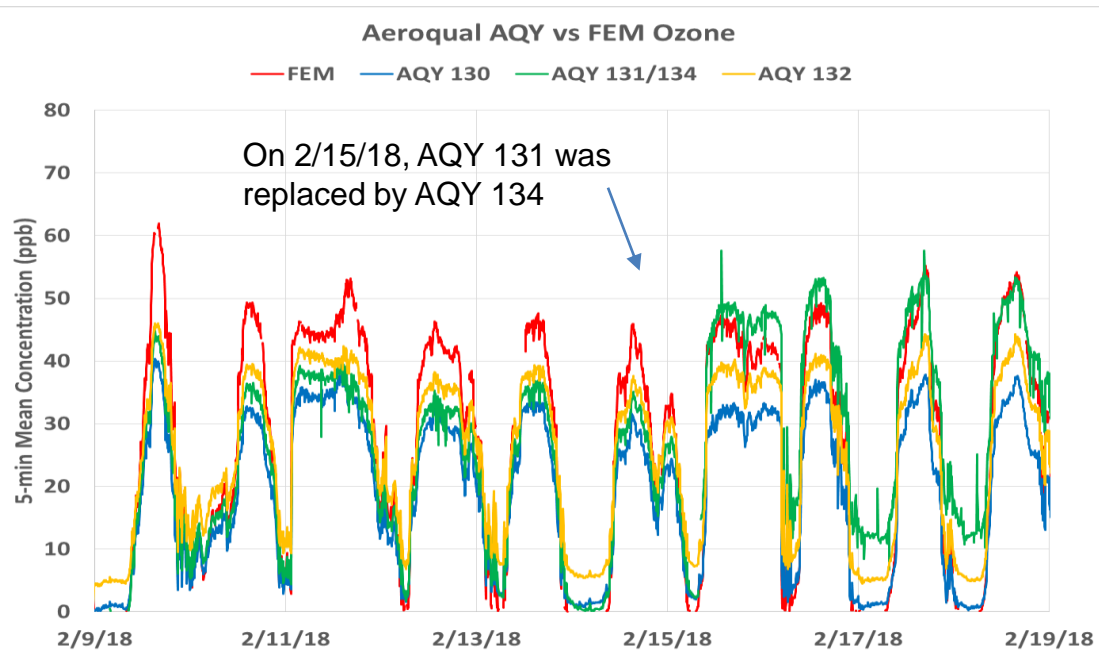
Aeroqual AQY vs FEM Ozone

— FEM — AQY 130 — AQY 131/134 — AQY 132

On 2/15/18, AQY 131 was replaced by AQY 134

- AQY Ozone measurements show an excellent correlation with the corresponding FEM data ($R^2 \sim 0.96$)
- The AQYs seem to track well the diurnal ozone variations recorded by the FEM instrument

Ozone (ppb; 5-min mean)
$y = 1.438x - 1.4532$
$R^2 = 0.9514$
AQY 130

Ozone (ppb; 5-min mean)
$y = 1.2343x - 1.2815$
$R^2 = 0.9684$
AQY 131

Ozone (ppb; 5-min mean)
$y = 1.5153x - 22.029$
$R^2 = 0.9492$
AQY 134

Ozone (ppb; 5-min mean)
$y = 1.2611x - 6.6195$
$R^2 = 0.9635$
AQY 132

Aeroqual AQY vs FEM (Ozone; 1-hr mean)

Aeroqual AQY vs FEM Ozone

— FEM — AQY 130 — AQY 131/134 — AQY 132

On 2/15/18, AQY 131 was replaced by AQY 134

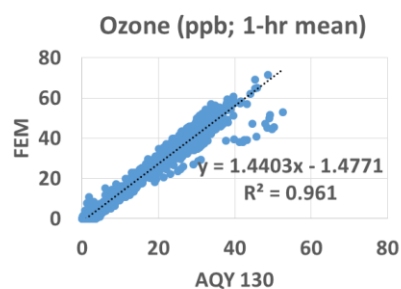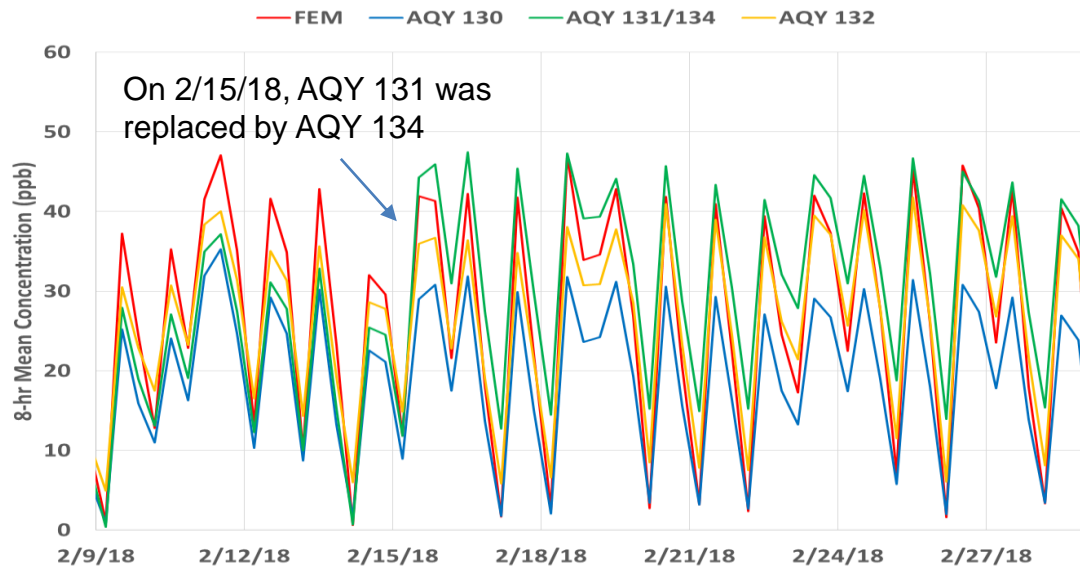- AQY Ozone measurements show an excellent correlation with the corresponding FEM data ($R^2 \sim 0.96$)
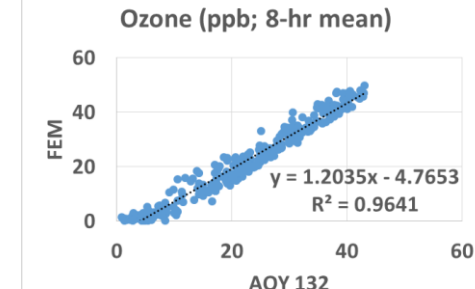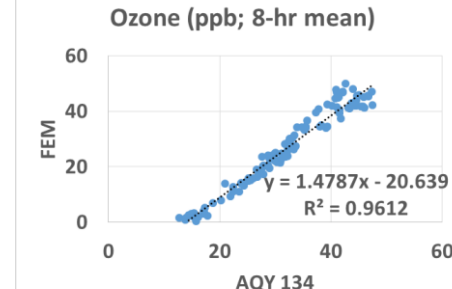- The AQYs seem to track well the diurnal ozone variations recorded by the FEM instrument

Ozone (ppb; 1-hr mean)

$y = 1.4403x - 1.4771$
$R^2 = 0.961$

AQY 130

Ozone (ppb; 1-hr mean)

$y = 1.2298x - 1.0974$
$R^2 = 0.9761$

AQY 131

Ozone (ppb; 1-hr mean)

$y = 1.5157x - 22.026$
$R^2 = 0.9612$

AQY 134

Ozone (ppb; 1-hr mean)

$y = 1.2545x - 6.4263$
$R^2 = 0.9678$

AQY 132

Aeroqual AQY vs FEM (Ozone; 8-hr mean)

Aeroqual AQY vs FEM Ozone

— FEM — AQY 130 — AQY 131/134 — AQY 132

On 2/15/18, AQY 131 was replaced by AQY 134

- AQY Ozone measurements show an excellent correlation with the corresponding FEM data ($R^2 \sim 0.96$)
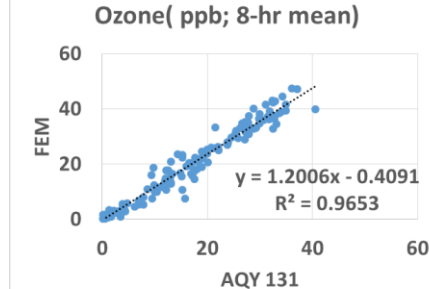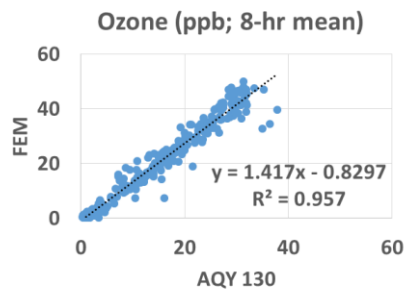- The AQYs seem to track well the diurnal ozone variations recorded by the FEM instrument

Ozone (ppb; 8-hr mean)

$y = 1.417x - 0.8297$
$R^2 = 0.957$
AQY 130

Ozone(ppb; 8-hr mean)

$y = 1.2006x - 0.4091$
$R^2 = 0.9653$
AQY 131

Ozone (ppb; 8-hr mean)

$y = 1.4787x - 20.639$
$R^2 = 0.9612$
AQY 134

Ozone (ppb; 8-hr mean)

$y = 1.2035x - 4.7653$
$R^2 = 0.9641$
AQY 132

Nitrogen Dioxide (NO_2) in AQY

NO$_2$ Data Handling

During this AQ-SPEC field evaluation, Aeroqual corrected and calculated NO$_2$ in all four units, using two different approaches:

1st approach (in this report, pollutant referred to as NO$_2$):
- NO$_2$ with correction for O$_3$ bias using AQY ozone data in real-time
- Calculation by on-instrument Aeroqual algorithm

2nd approach (in this report, pollutant referred to as NO$_2$ V2)
- NO$_2$ with correction for O$_3$ and RH bias using AQY ozone and AQY RH data in real-time
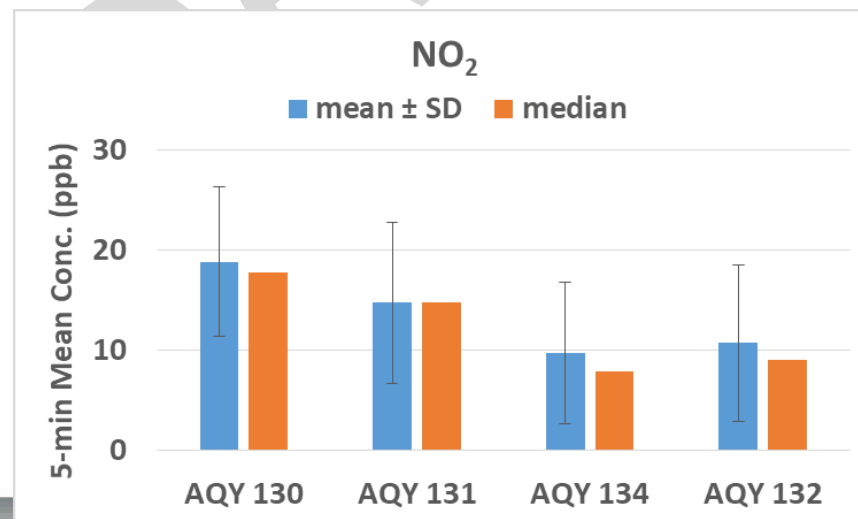- Calculation by <u>new</u> on-instrument Aeroqual algorithm

To better assist in understanding the procedures mentioned above, Aeroqual has shared all related proprietary information with AQ-SPEC
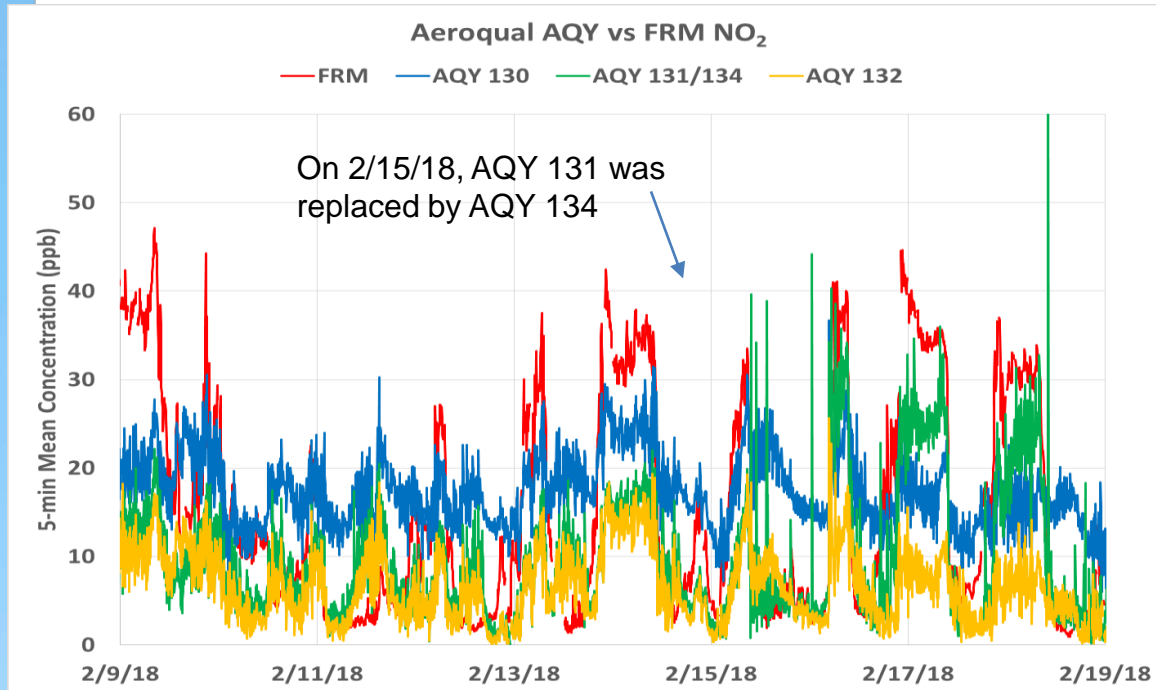
Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for **NO_2** in the four AQYs was high (i.e., 98% for AQY 130; 95% for AQY 131; 85% for AQY 132 and 92% for AQY 134).
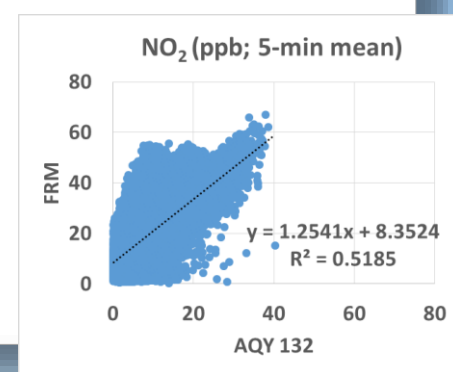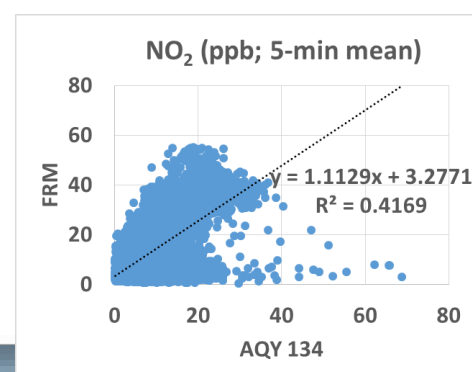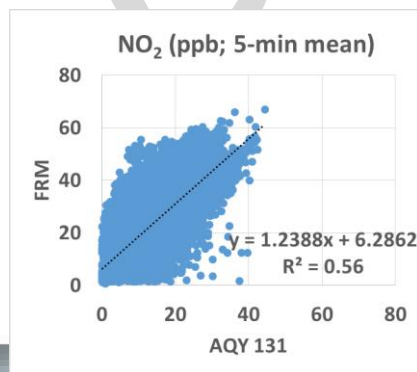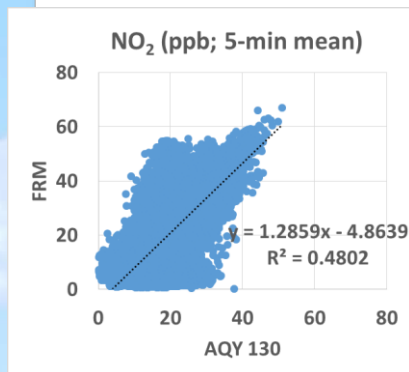
Aeroqual AQY; Intra-model variability

- Substantial measurement variability was observed between the two AQY units (130, 132) for nitrogen dioxide during the entire deployment period.

Aeroqual AQY vs FRM (NO$_2$; 5-min mean)

Aeroqual AQY vs FRM NO$_2$

— FRM — AQY 130 — AQY 131/134 — AQY 132

On 2/15/18, AQY 131 was replaced by AQY 134

- AQY NO$_2$ measurements show a moderate correlation with the corresponding FRM data ($R^2 \sim 0.50$)
- The AQYs seem to track the diurnal NO$_2$ variations recorded by the FRM instrument

NO$_2$ (ppb; 5-min mean)

$y = 1.2859x - 4.8639$
$R^2 = 0.4802$

NO$_2$ (ppb; 5-min mean)

$y = 1.2388x + 6.2862$
$R^2 = 0.56$

NO$_2$ (ppb; 5-min mean)

$y = 1.1129x + 3.2771$
$R^2 = 0.4169$

NO$_2$ (ppb; 5-min mean)

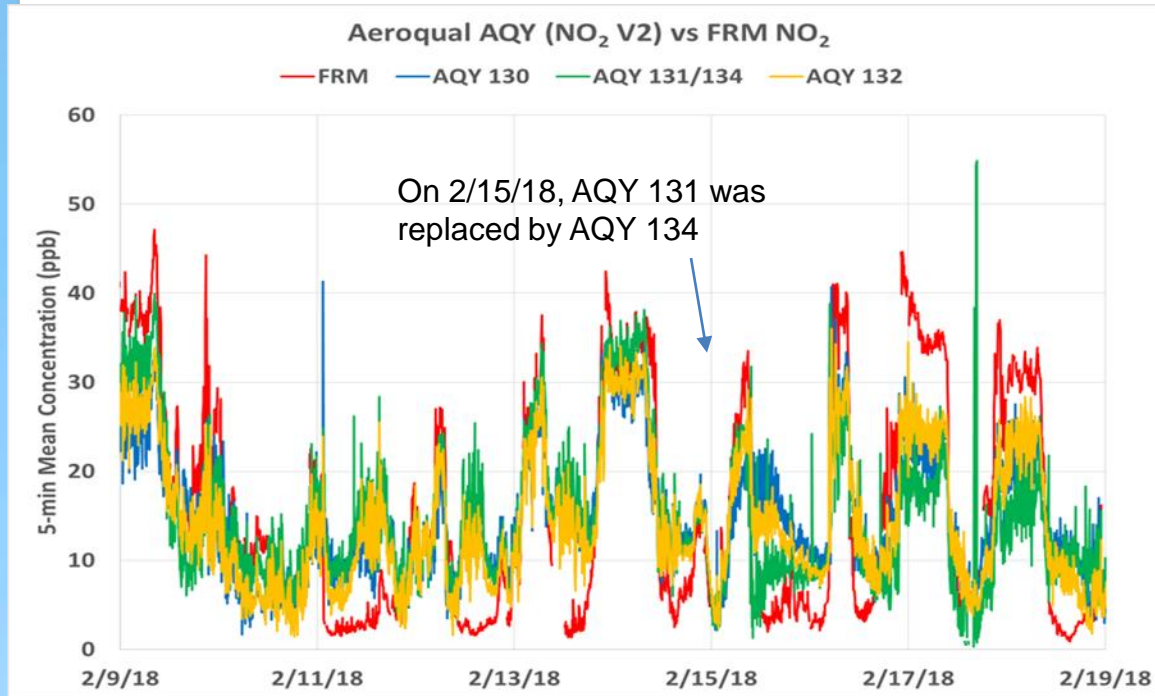$y = 1.2541x + 8.3524$
$R^2 = 0.5185$

Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- Data recovery for **NO_2 V2** in the four AQYs was high (i.e., 98% for AQY 130; 99% for AQY 131; 97% for AQY 132 and 99% for AQY 134).
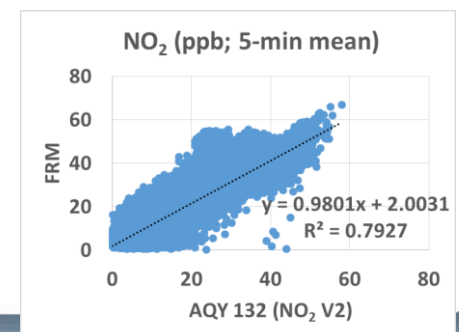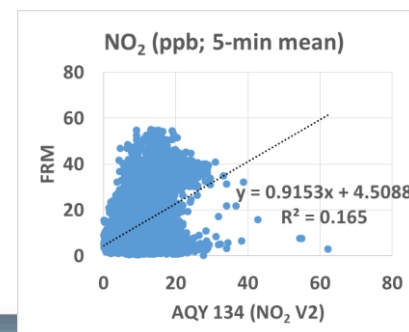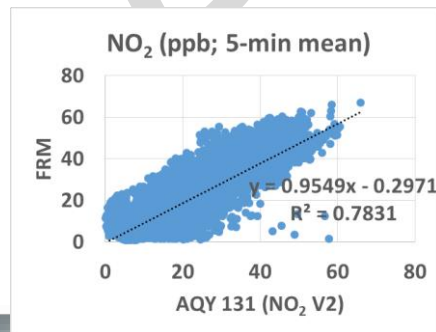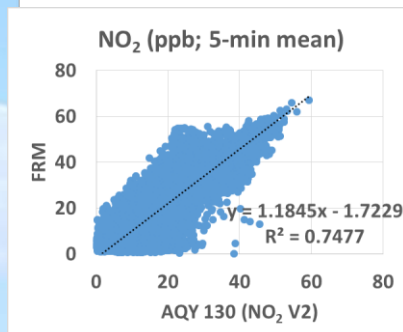
Aeroqual AQY; Intra-model variability

- Very low measurement variability was observed between the two AQY units (130, 132) for nitrogen dioxide (V2) during the entire deployment period.
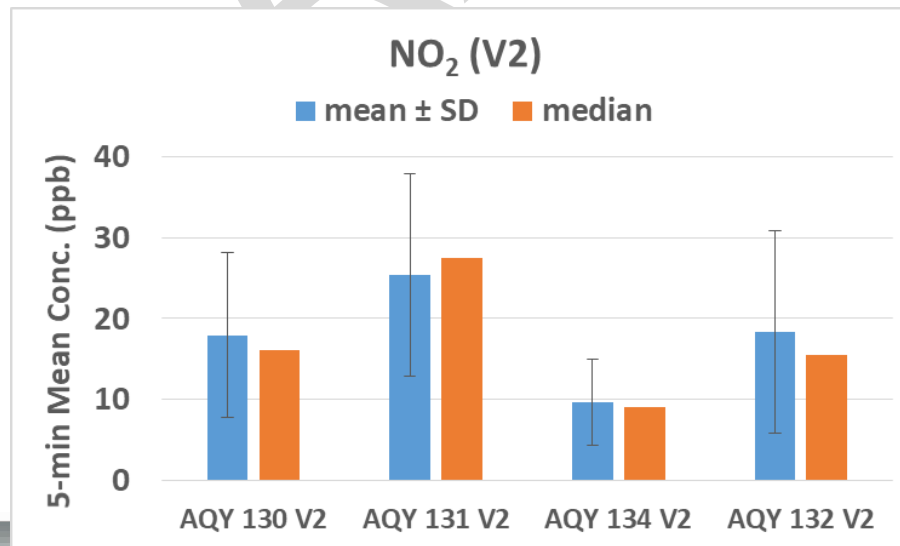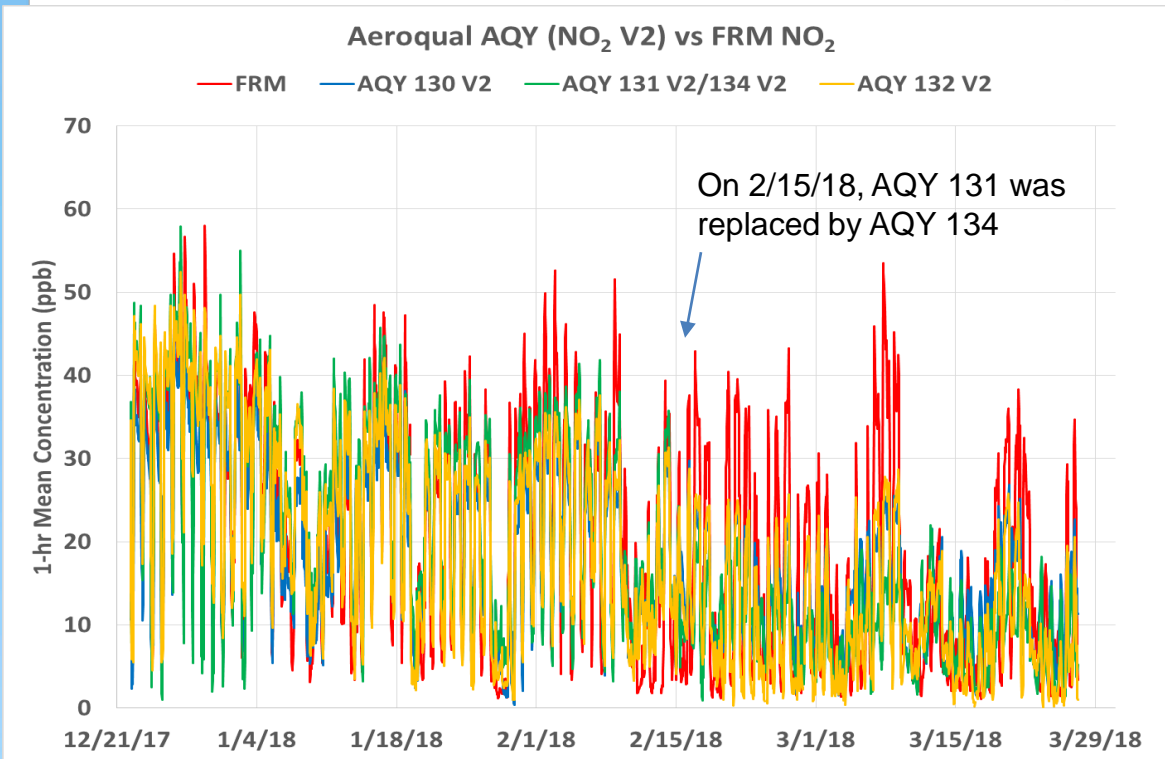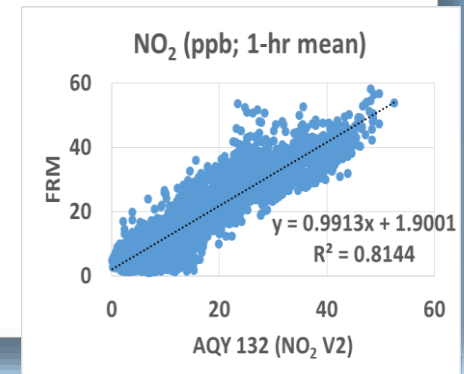
Aeroqual AQY vs FRM (NO$_2$; 5-min mean)

Aeroqual AQY (NO$_2$ V2) vs FRM NO$_2$
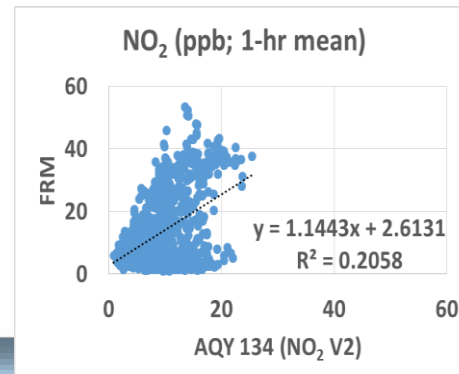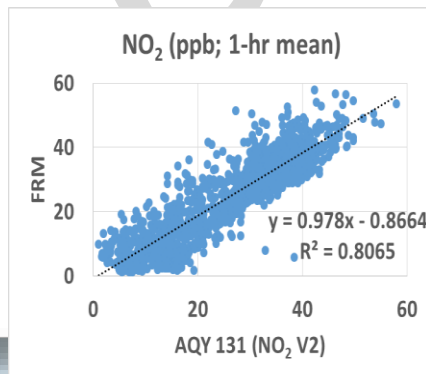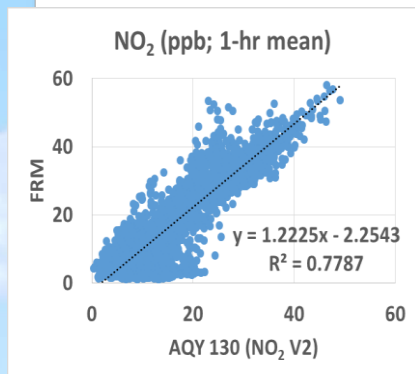
On 2/15/18, AQY 131 was replaced by AQY 134

- AQY NO$_2$ measurements in AQYs 130 and 132 correlate well with the corresponding FRM data ($R^2 \sim 0.77$)
- The two AQYs seem to be highly accurate
- The two AQYs seem to track the diurnal NO$_2$ variations recorded by the FRM instrument

NO$_2$ (ppb; 5-min mean)
$y = 1.1845x - 1.7229$
$R^2 = 0.7477$
AQY 130 (NO$_2$ V2)

NO$_2$ (ppb; 5-min mean)
$y = 0.9549x - 0.2971$
$R^2 = 0.7831$
AQY 131 (NO$_2$ V2)

NO$_2$ (ppb; 5-min mean)
$y = 0.9153x + 4.5088$
$R^2 = 0.165$
AQY 134 (NO$_2$ V2)

NO$_2$ (ppb; 5-min mean)
$y = 0.9801x + 2.0031$
$R^2 = 0.7927$
AQY 132 (NO$_2$ V2)

Aeroqual AQY vs FRM (NO$_2$; 1-hr mean)

Aeroqual AQY (NO$_2$ V2) vs FRM NO$_2$

FRM — AQY 130 V2 — AQY 131 V2/134 V2 — AQY 132 V2

On 2/15/18, AQY 131 was replaced by AQY 134

- AQY NO$_2$ measurements in AQYs 130 and 132 correlate well with the corresponding FRM data (R^2 ~ 0.79)
- The two AQYs seem to be highly accurate
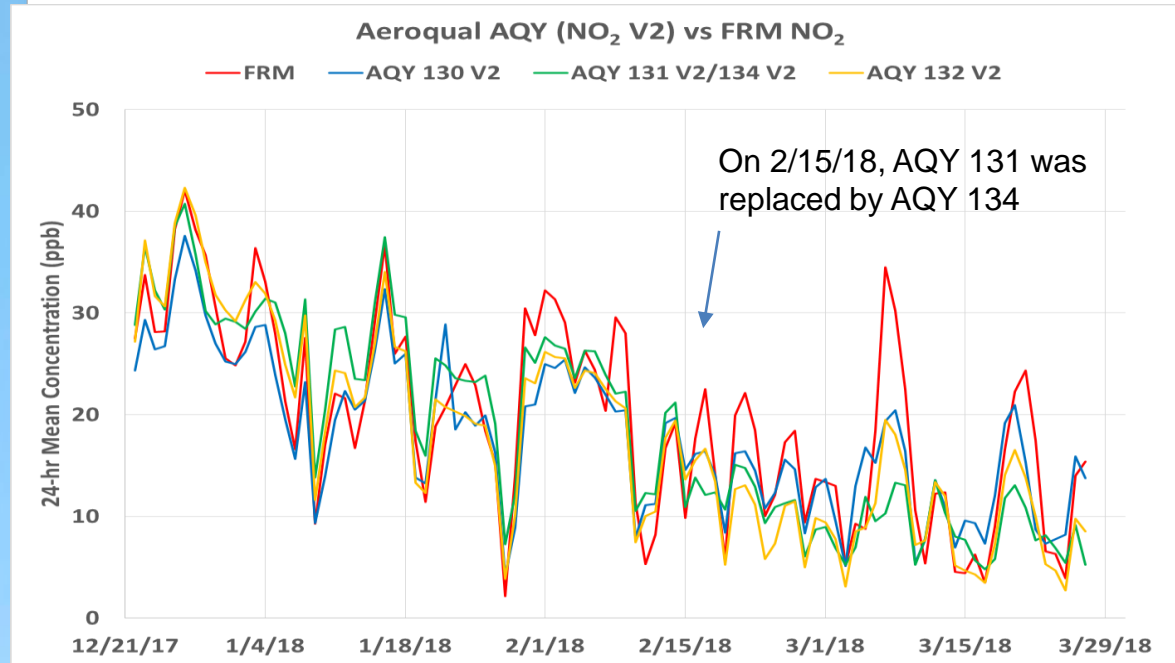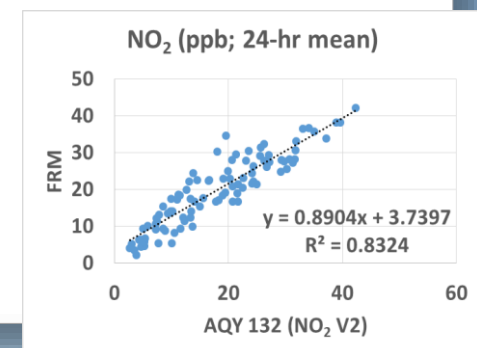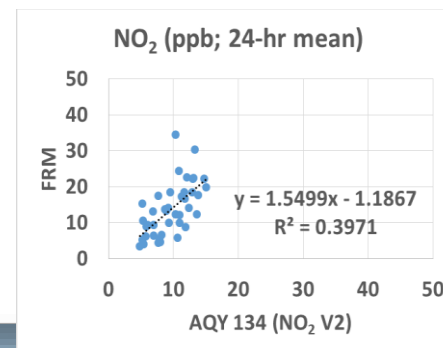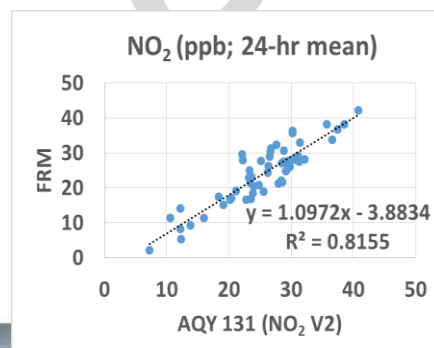- The two AQYs seem to track the diurnal NO$_2$ variations recorded by the FRM instrument

NO$_2$ (ppb; 1-hr mean)
$y = 1.2225x - 2.2543$
$R^2 = 0.7787$

NO$_2$ (ppb; 1-hr mean)
$y = 0.978x - 0.8664$
$R^2 = 0.8065$

NO$_2$ (ppb; 1-hr mean)
$y = 1.1443x + 2.6131$
$R^2 = 0.2058$

NO$_2$ (ppb; 1-hr mean)
$y = 0.9913x + 1.9001$
$R^2 = 0.8144$

Aeroqual AQY vs FRM (NO$_2$; 24-hr mean)

Aeroqual AQY (NO$_2$ V2) vs FRM NO$_2$

— FRM   — AQY 130 V2   — AQY 131 V2/134 V2   — AQY 132 V2

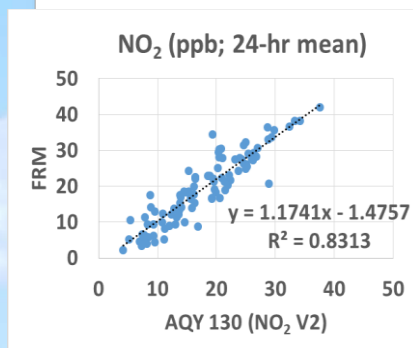On 2/15/18, AQY 131 was replaced by AQY 134

- AQY NO$_2$ measurements in AQYs 130 and 132 correlate very well with the corresponding FRM data (R^2 ~ 0.83)
- The two AQYs seem to be highly accurate
- The two AQYs seem to track the diurnal NO$_2$ variations recorded by the FRM instrument

NO$_2$ (ppb; 24-hr mean)

$y = 1.1741x - 1.4757$
$R^2 = 0.8313$

AQY 130 (NO$_2$ V2)

NO$_2$ (ppb; 24-hr mean)

$y = 1.0972x - 3.8834$
$R^2 = 0.8155$

AQY 131 (NO$_2$ V2)

NO$_2$ (ppb; 24-hr mean)

$y = 1.5499x - 1.1867$
$R^2 = 0.3971$

AQY 134 (NO$_2$ V2)

NO$_2$ (ppb; 24-hr mean)

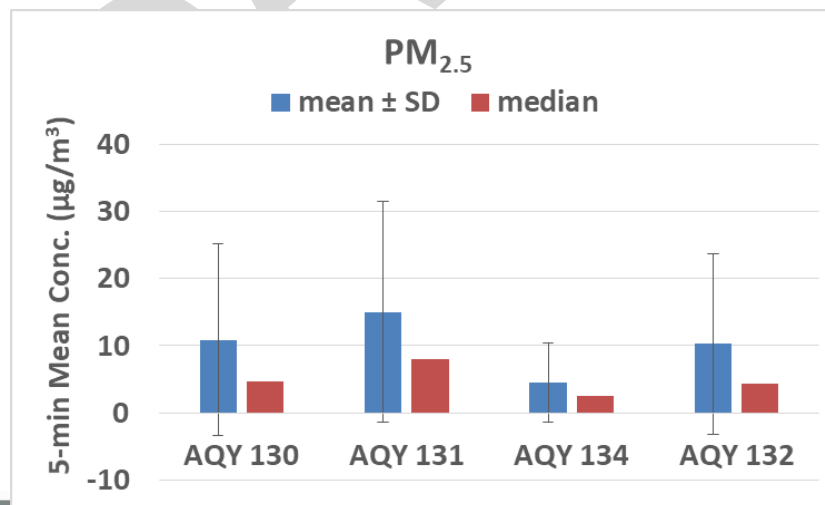$y = 0.8904x + 3.7397$
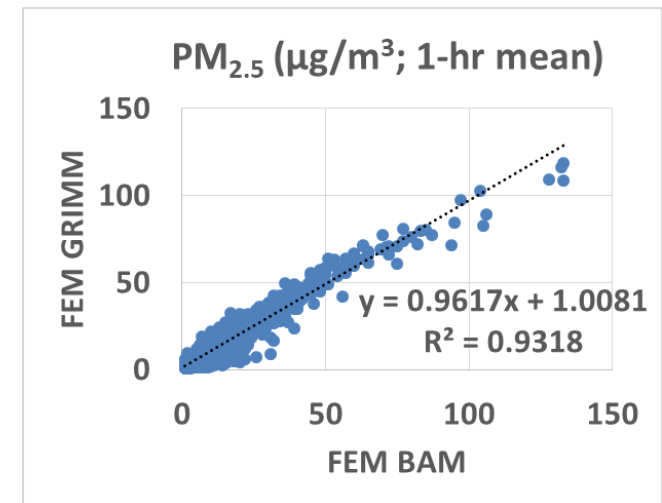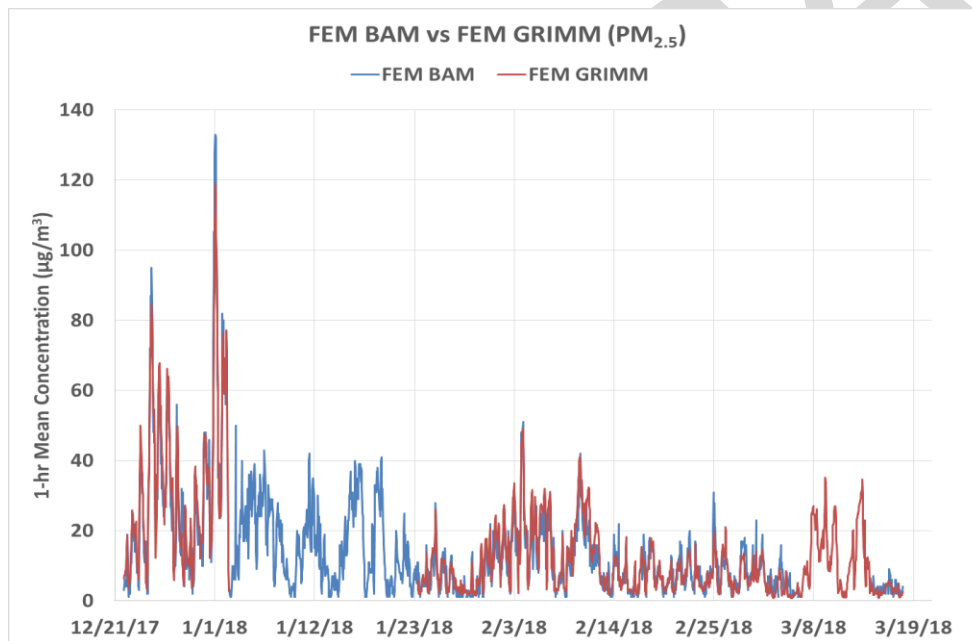$R^2 = 0.8324$

AQY 132 (NO$_2$ V2)

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PM$_{2.5}$ in AQY

Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e., obvious outliers, negative values, and invalid data-points were eliminated from the data-set)
- AQY $PM_{2.5}$ was corrected based on AQY RH data in real-time
- Data recovery for $PM_{2.5}$ in the four AQYs was excellent (i.e., 99% for AQY 130; 100% for AQY 131, AQY 132 and AQY 134).

Aeroqual AQY; Intra-model variability

- Very low measurement variability was observed between the two AQY units (130, 132) for $PM_{2.5}$ during the entire deployment period.
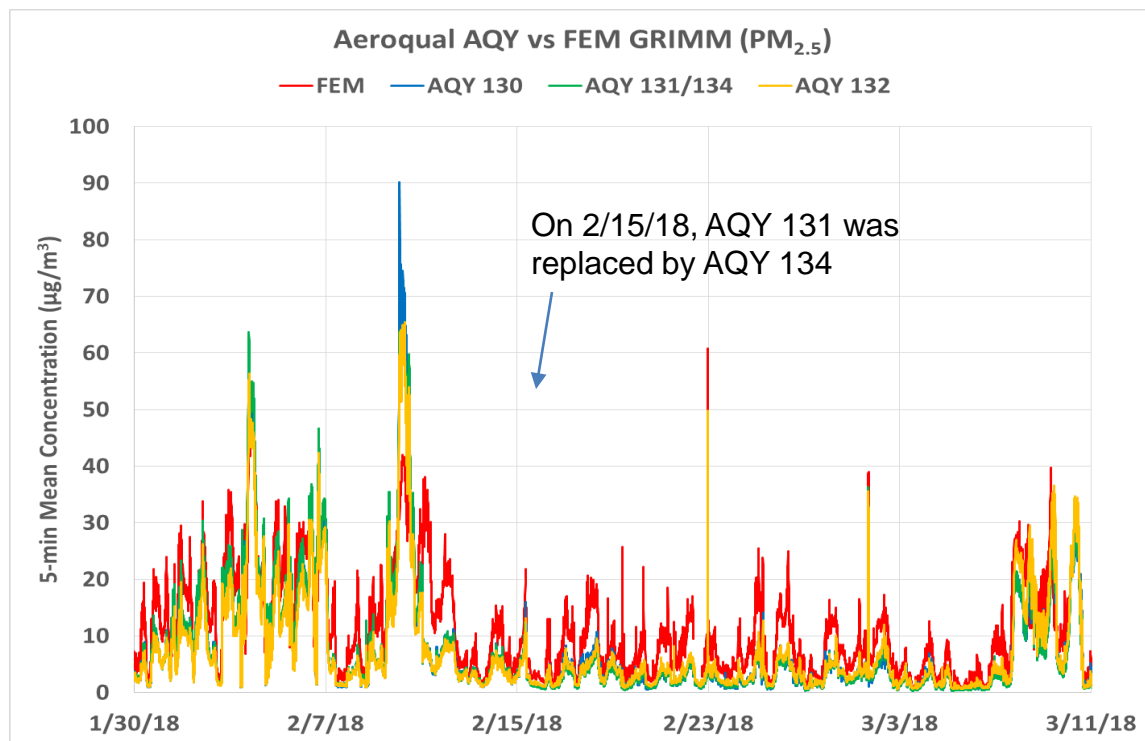
Data validation & recovery

- Basic QA/QC procedures were used to validate the collected FEM data (i.e. obvious outliers, negative values and invalid data-points were eliminated from data-set)
- $PM_{2.5}$ data recovery was 68 % for the GRIMM and 88 % for the BAM.
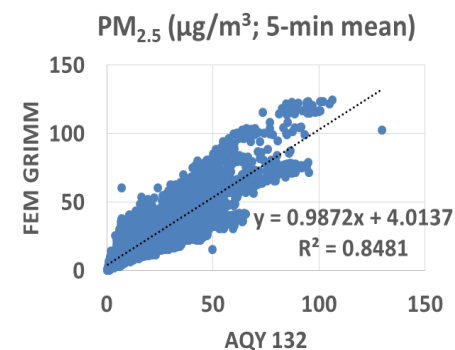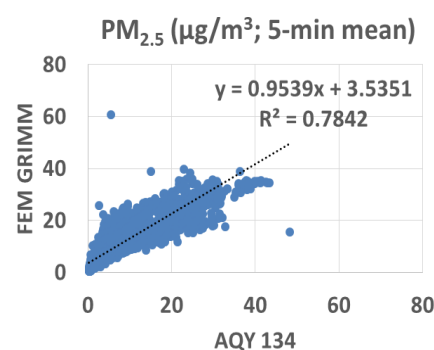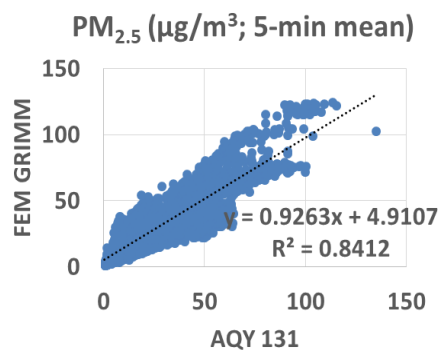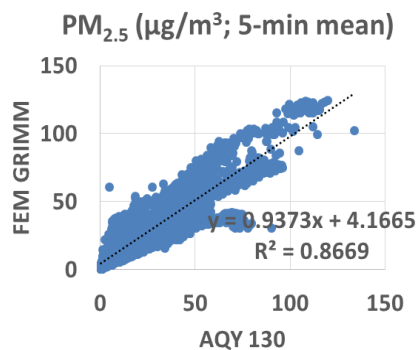
Equivalent methods: BAM vs GRIMM

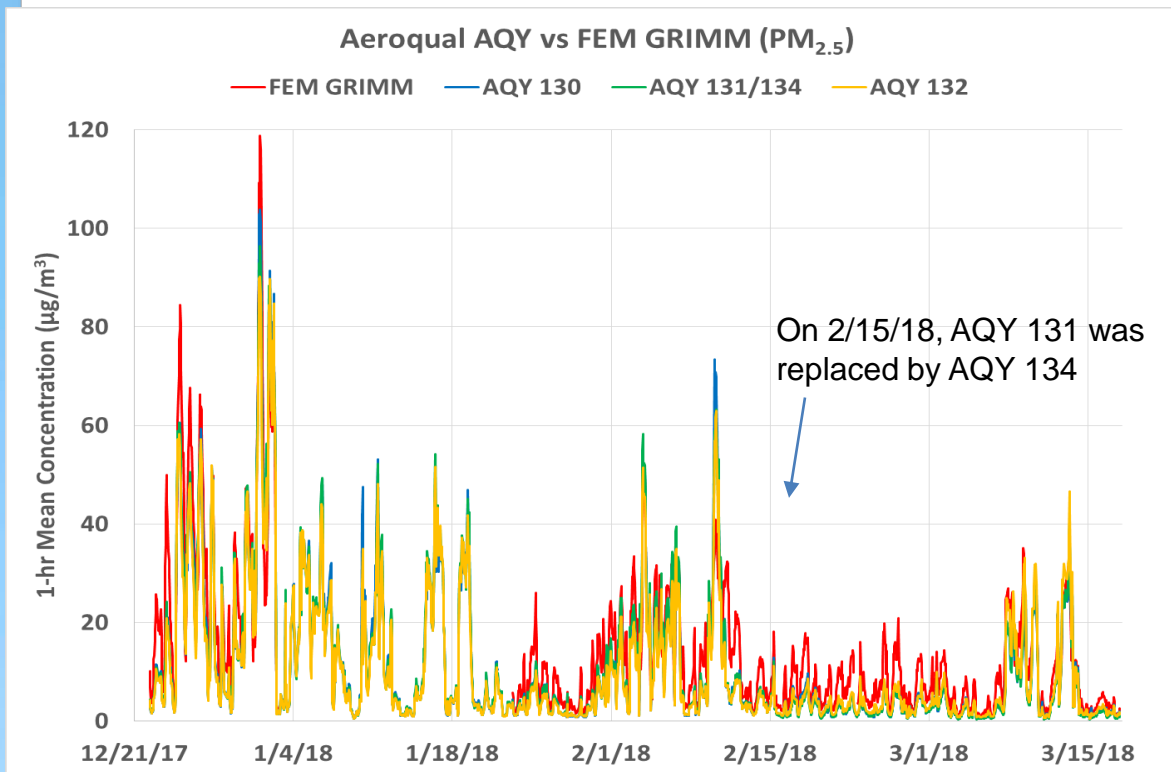- Excellent agreement between the two equivalent methods for $PM_{2.5}$

FEM BAM vs FEM GRIMM ($PM_{2.5}$)
— FEM BAM — FEM GRIMM

$PM_{2.5}$ ($\mu g/m^3$; 1-hr mean)

$y = 0.9617x + 1.0081$
$R^2 = 0.9318$

Aeroqual AQY vs FEM (GRIMM PM$_{2.5}$; 5-min mean)

Aeroqual AQY vs FEM GRIMM (PM$_{2.5}$)

— FEM   — AQY 130   — AQY 131/134   — AQY 132
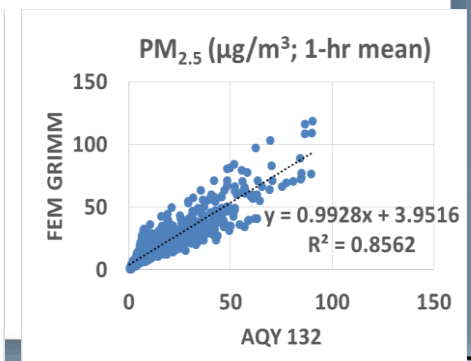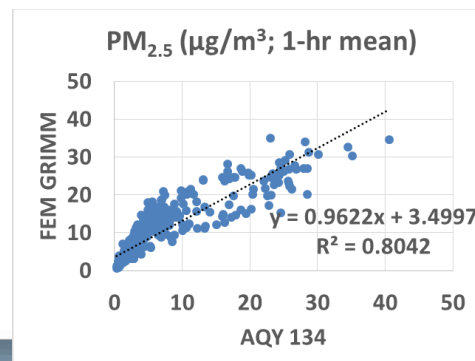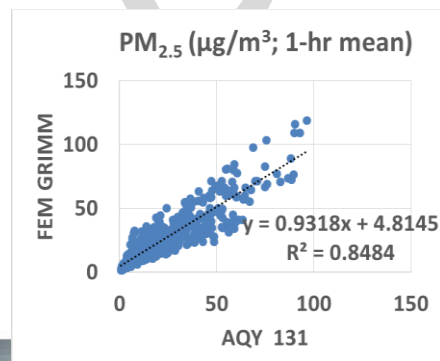
On 2/15/18, AQY 131 was replaced by AQY 134

- AQY PM$_{2.5}$ measurements in AQYs 130 and 132 correlate very well with the corresponding FEM GRIMM data (R^2 ~ 0.86)
- The two AQYs seem to be highly accurate
- The two AQYs seem to track well the diurnal PM$_{2.5}$ variations recorded by the FEM GRIMM instrument

PM$_{2.5}$ (µg/m³; 5-min mean)

$y = 0.9373x + 4.1665$
$R^2 = 0.8669$

PM$_{2.5}$ (µg/m³; 5-min mean)

$y = 0.9263x + 4.9107$
$R^2 = 0.8412$

PM$_{2.5}$ (µg/m³; 5-min mean)

$y = 0.9539x + 3.5351$
$R^2 = 0.7842$

PM$_{2.5}$ (µg/m³; 5-min mean)

$y = 0.9872x + 4.0137$
$R^2 = 0.8481$
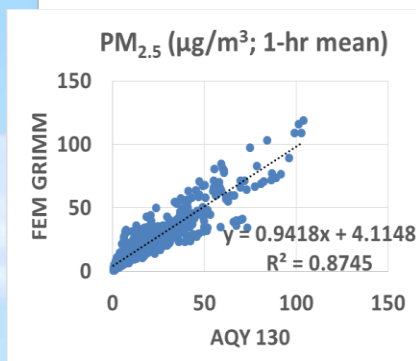
Aeroqual AQY vs FEM (GRIMM PM$_{2.5}$; 1-hr mean)

- AQY PM$_{2.5}$ measurements in AQYs 130 and 132 correlate very well with the corresponding FEM GRIMM data (R^2 ~ 0.86)
- The two AQYs seem to be highly accurate
- The two AQYs seem to track well the diurnal PM$_{2.5}$ variations recorded by the FEM GRIMM instrument
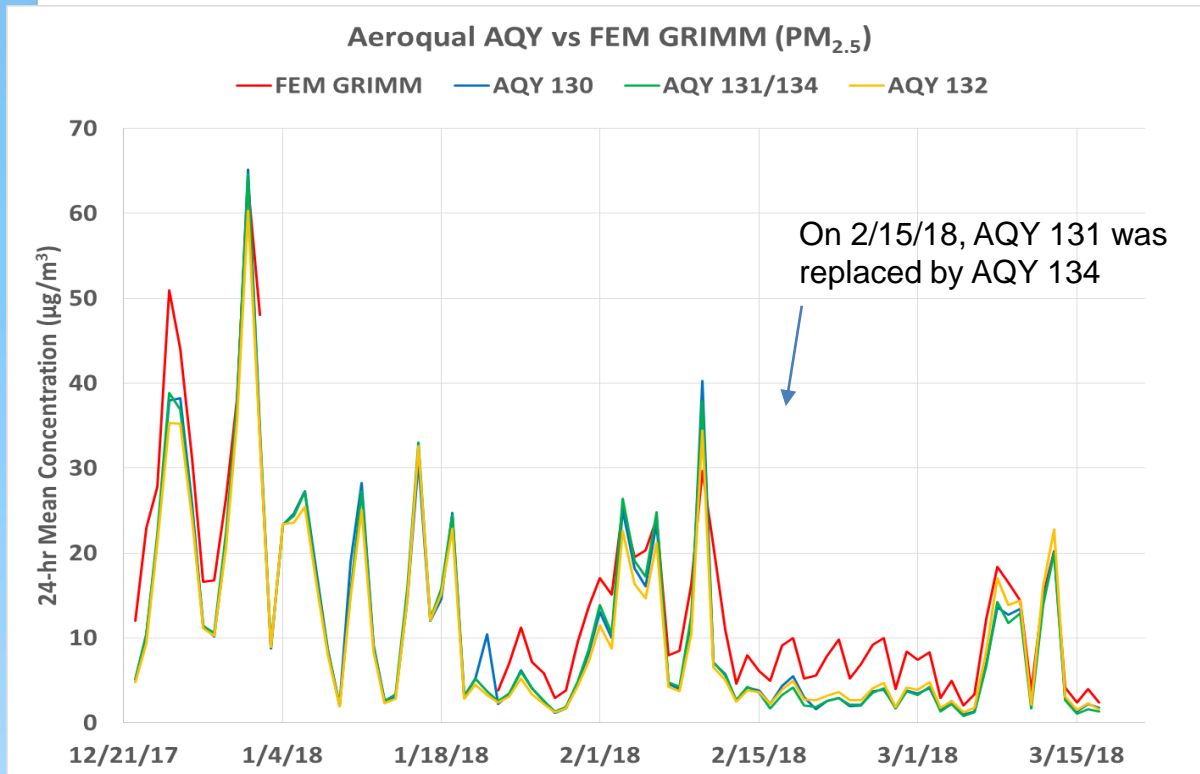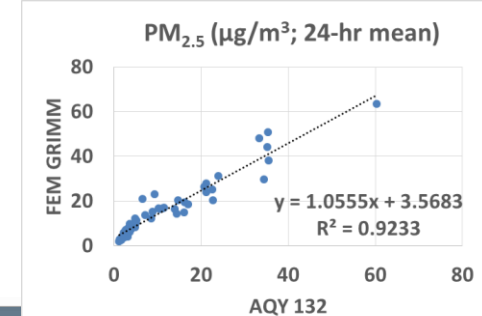
Aeroqual AQY vs FEM (GRIMM PM$_{2.5}$; 24-hr mean)

Aeroqual AQY vs FEM GRIMM (PM$_{2.5}$)

Legend: FEM GRIMM — AQY 130 — AQY 131/134 — AQY 132
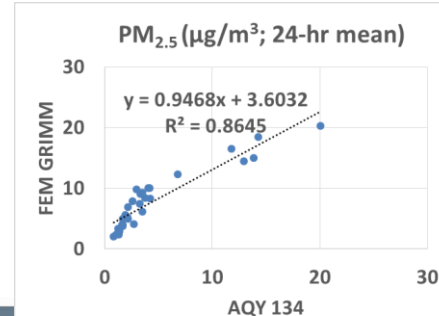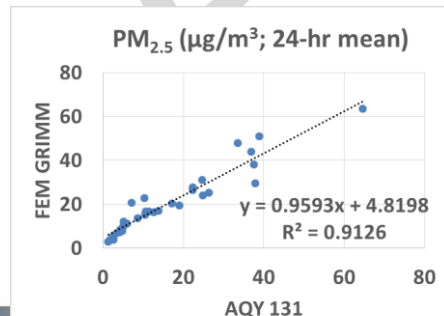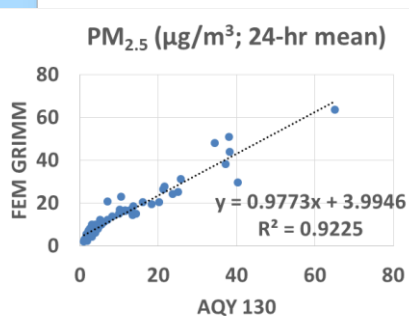
On 2/15/18, AQY 131 was replaced by AQY 134

- AQY PM$_{2.5}$ measurements in AQYs 130 and 132 correlate very well with the corresponding FEM GRIMM data (R^2 ~ 0.92)
- The two AQYs seem to be highly accurate
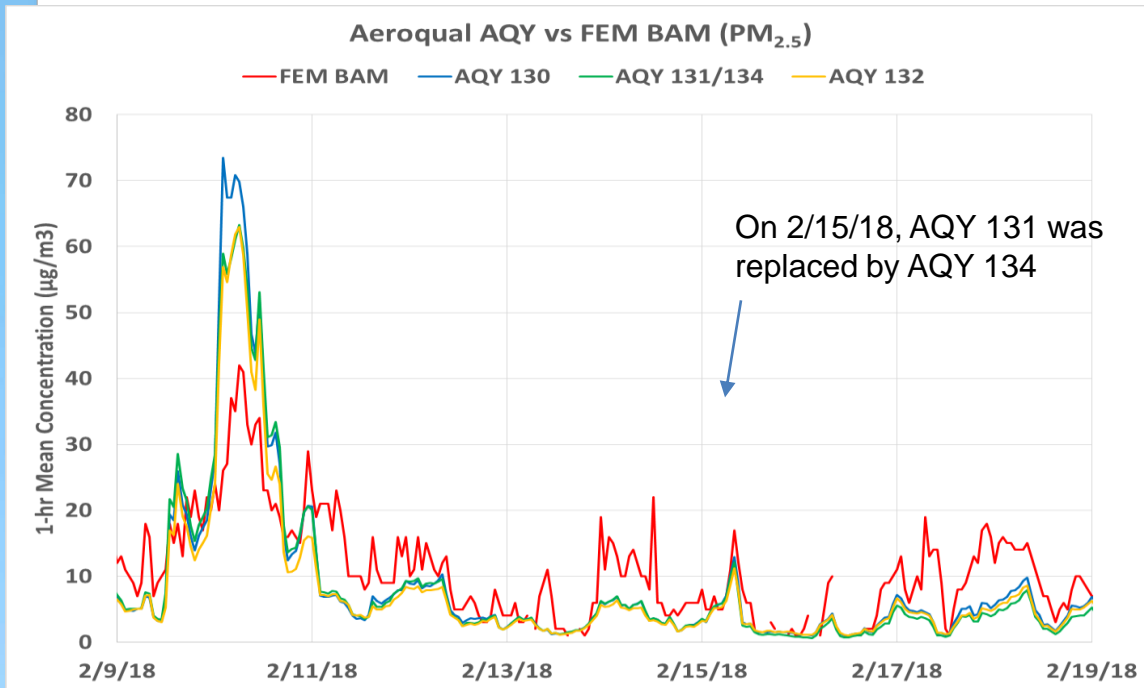- The two AQYs seem to track well the diurnal PM$_{2.5}$ variations recorded by the FEM GRIMM instrument

PM$_{2.5}$ (μg/m^3; 24-hr mean)

$y = 0.9773x + 3.9946$
$R^2 = 0.9225$

PM$_{2.5}$ (μg/m^3; 24-hr mean)

$y = 0.9593x + 4.8198$
$R^2 = 0.9126$

PM$_{2.5}$ (μg/m^3; 24-hr mean)

$y = 0.9468x + 3.6032$
$R^2 = 0.8645$

PM$_{2.5}$ (μg/m^3; 24-hr mean)

$y = 1.0555x + 3.5683$
$R^2 = 0.9233$

Aeroqual AQY vs FEM (BAM PM$_{2.5}$; 1-hr mean)

Aeroqual AQY vs FEM BAM (PM$_{2.5}$)

— FEM BAM — AQY 130 — AQY 131/134 — AQY 132
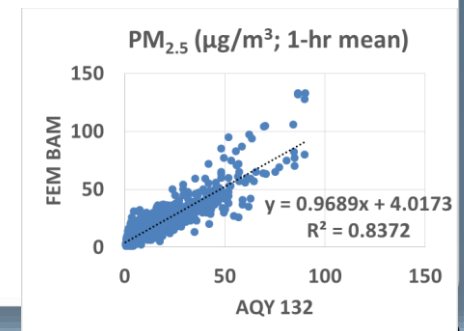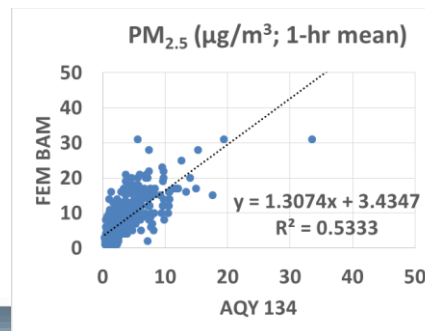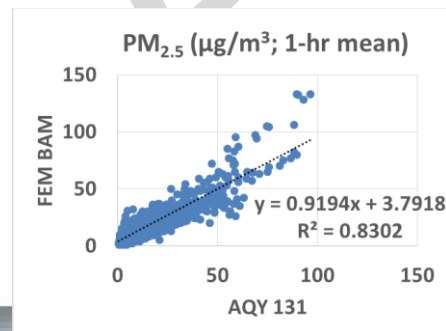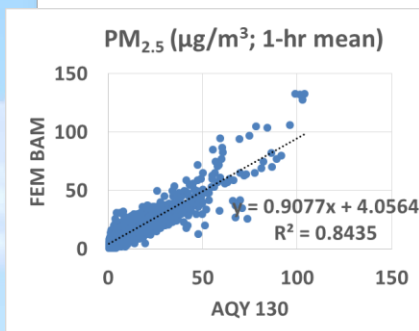
On 2/15/18, AQY 131 was replaced by AQY 134

- AQY PM$_{2.5}$ measurements in AQYs 130 and 132 correlate very well with the corresponding FEM BAM data (R^2 ~ 0.84)
- The two AQYs seem to be highly accurate
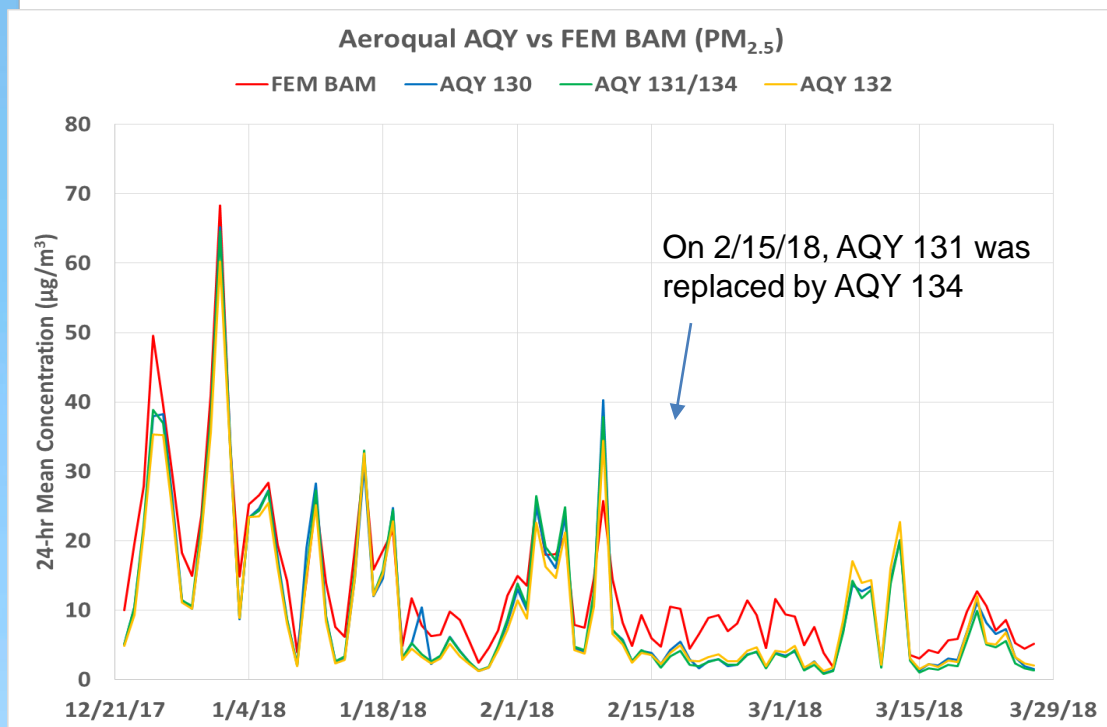- The two AQYs seem to track the diurnal PM$_{2.5}$ variations recorded by the FEM BAM instrument

PM$_{2.5}$ (µg/m³; 1-hr mean)

y = 0.9077x + 4.0564
R^2 = 0.8435

PM$_{2.5}$ (µg/m³; 1-hr mean)

y = 0.9194x + 3.7918
R^2 = 0.8302

PM$_{2.5}$ (µg/m³; 1-hr mean)

y = 1.3074x + 3.4347
R^2 = 0.5333

PM$_{2.5}$ (µg/m³; 1-hr mean)

y = 0.9689x + 4.0173
R^2 = 0.8372

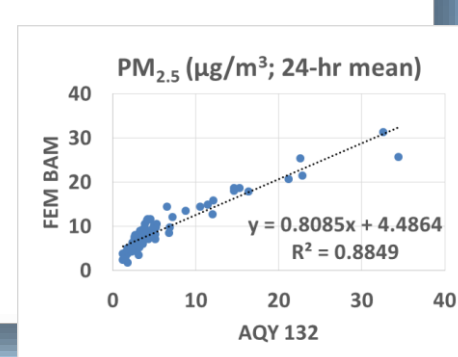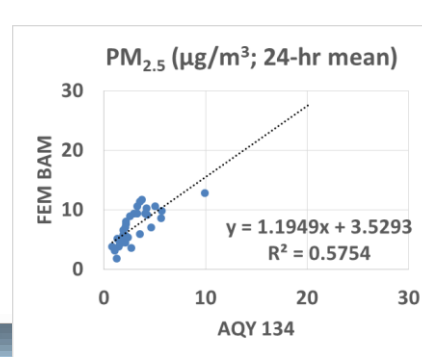# Aeroqual AQY vs FEM (BAM PM$_{2.5}$; 24-hr mean)
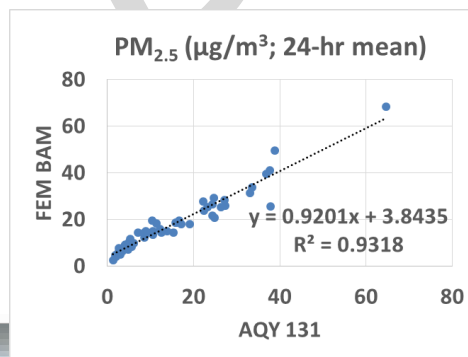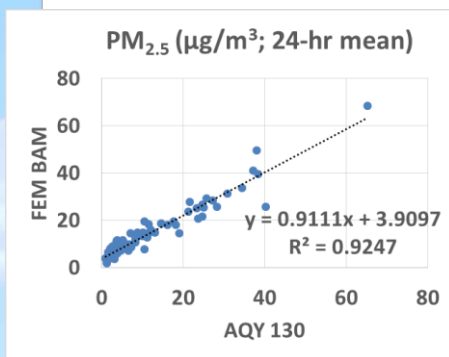

- AQY PM$_{2.5}$ measurements in AQYs 130 and 132 correlate very well with the corresponding FEM BAM data (R^2 ~ 0.90)
- The two AQYs seem to be highly accurate
- The two AQYs seem to track the diurnal PM$_{2.5}$ variations recorded by the FEM BAM instrument
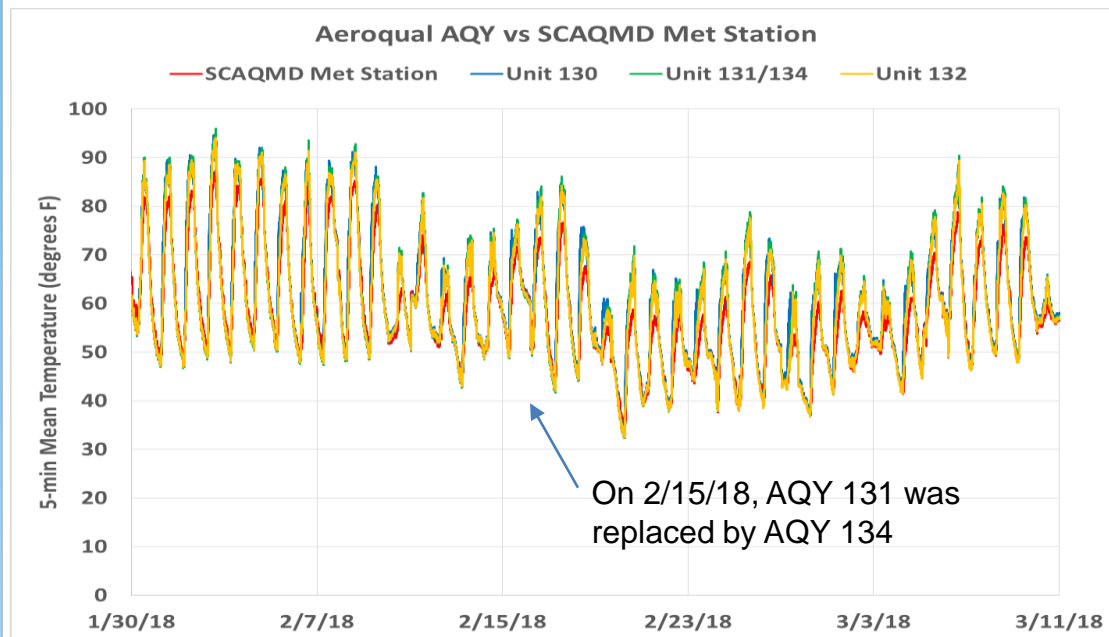
Aeroqual AQY vs SCAQMD Met Station (Temp; 5-min mean)

Aeroqual AQY vs SCAQMD Met Station

— SCAQMD Met Station — Unit 130 — Unit 131/134 — Unit 132

On 2/15/18, AQY 131 was replaced by AQY 134
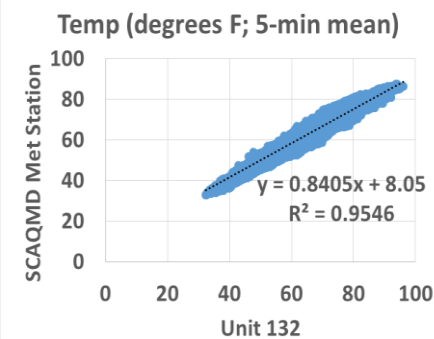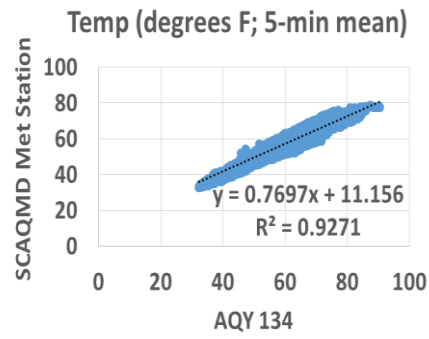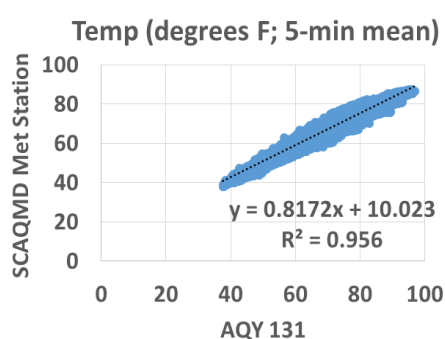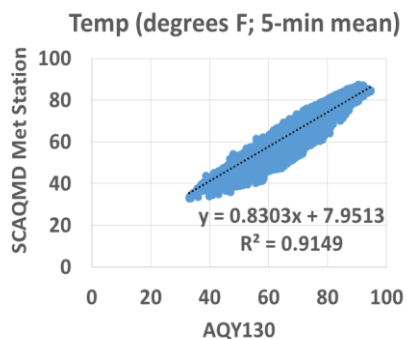
- AQY Temp measurements in AQYs 130 and 132 correlate very well with the corresponding SCAQMD Met Station sensor ($R^2 \sim 0.93$)
- The two AQYs seem to be highly accurate
- The two AQYs seem to track the diurnal Temp variations recorded by the SCAQMD Met station sensor

Temp (degrees F; 5-min mean)

$y = 0.8303x + 7.9513$
$R^2 = 0.9149$

Temp (degrees F; 5-min mean)

$y = 0.8172x + 10.023$
$R^2 = 0.956$

Temp (degrees F; 5-min mean)

$y = 0.7697x + 11.156$
$R^2 = 0.9271$

Temp (degrees F; 5-min mean)

$y = 0.8405x + 8.05$
$R^2 = 0.9546$

Aeroqual AQY vs SCAQMD Met Station (RH; 5-min mean)

Aeroqual AQY vs SCAQMD Met Station

Legend: SCAQMD Met Station — AQY 130 — AQY 131/134 — AQY 132

On 2/15/18, AQY 131 was replaced by AQY 134

- AQY RH measurements in AQYs 130 and 132 correlate very well with the corresponding SCAQMD Met Station sensor ($R^2 \sim 0.96$)
- The two AQYs seem to be highly accurate
- The two AQYs seem to track the diurnal RH variations recorded by the SCAQMD Met station sensor
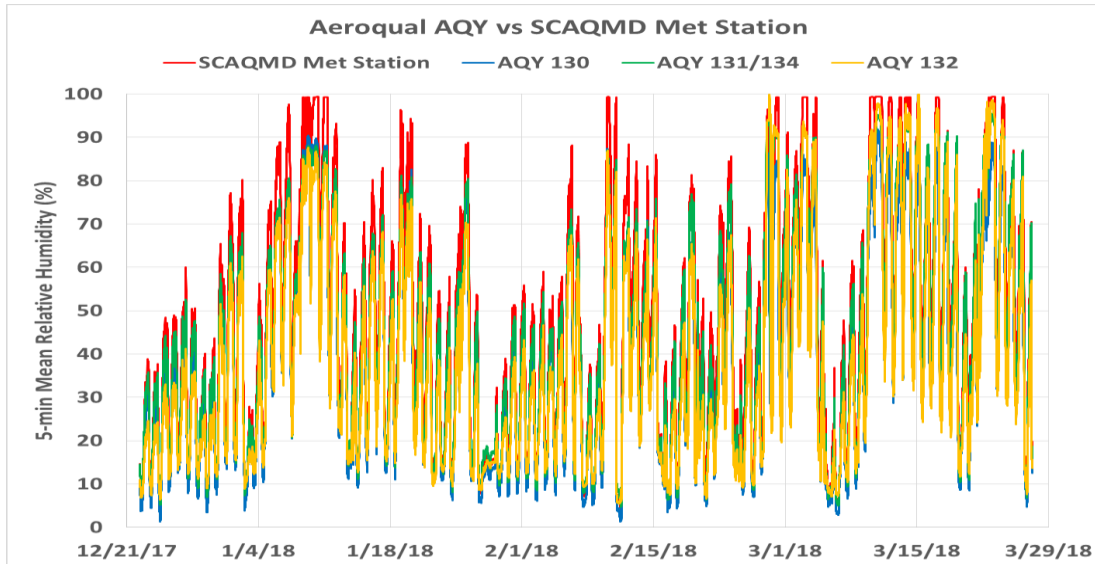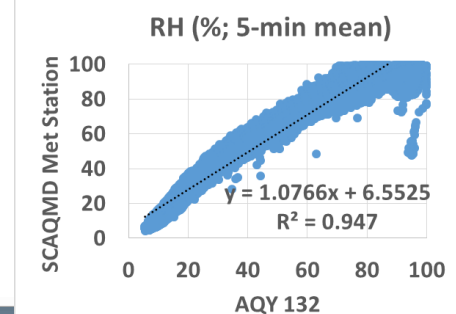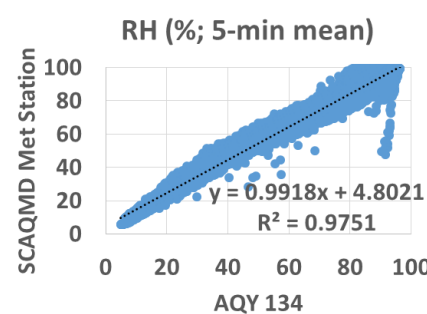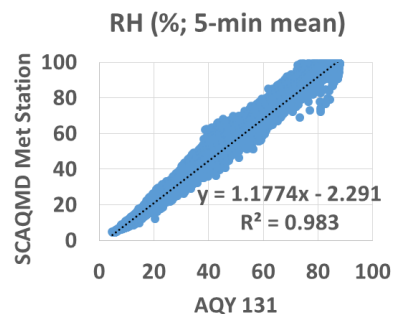
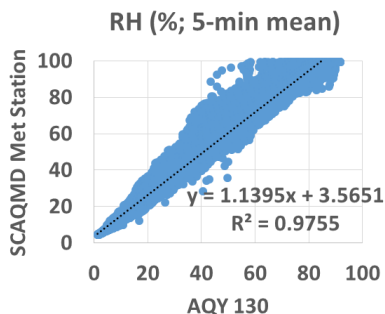**RH (%; 5-min mean)** — AQY 130
$$y = 1.1395x + 3.5651$$
$$R^2 = 0.9755$$

RH (%; 5-min mean) — AQY 131
$$y = 1.1774x - 2.291$$
$$R^2 = 0.983$$

RH (%; 5-min mean) — AQY 134
$$y = 0.9918x + 4.8021$$
$$R^2 = 0.9751$$

RH (%; 5-min mean) — AQY 132
$$y = 1.0766x + 6.5525$$
$$R^2 = 0.947$$

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Discussion

- With the exception of a faulty NO_2 sensor in one of the three units (AQY 131), the **Aeroqual AQY v0.5** multi-sensor units (AQY 130 and 132) performed very well and showed:
  - ➢ Minimal down-time: data recovery from each unit was higher than 90%
  - ➢ Low intra-model variability for all measured pollutants

- During the <u>entire</u> field deployment testing period:
  - ➢ Ozone sensors showed excellent correlation with a more expensive FEM instrument ($R^2 > 0.95$)
  - ➢ NO_2 V2 sensors showed very good correlation with a more expensive FRM instrument ($R^2 > 0.74$) and high accuracy
  - ➢ $PM_{2.5}$ sensors showed very good correlation with more expensive FEM instruments (GRIMM: $R^2 > 0.84$ and BAM: $R^2 > 0.83$) and high accuracy
  - ➢ Temperature and relative humidity sensors showed excellent correlation with the SCAQMD Met Station sensors (T: $R^2 > 0.91$ and RH: $R^2 > 0.94$)

- No sensor calibration was performed by AQ-SPEC prior to the beginning of this field testing
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under controlled T and RH conditions, and known target and interferent pollutants concentrations.
- These results are still preliminary